



PRINCIPLES OF MODERN CHEMISTRY

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APPLICANT'S
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D

DAVID W. OXTOBY

The University of Chicago

NORMAN H. NACHTRIEB†

The University of Chicago

University of Illinois at Chicago

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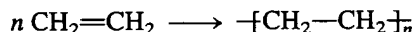
Table 23-5: Plastics

Name	Structural Units	Properties	Sample Uses
Polyethylene	$-(CH_2-CH_2)_n-$	High density: hard, strong, stiff. Low density: soft, flexible, clear	Molded containers, lids, toys, pipe Packaging, trash bags, squeeze bottles
Polypropylene	$-(CH_2-\underset{\text{CH}_3}{\text{CH}})_n-$	Stiffer, harder than high-density polyethylene; higher melting point	Containers, lids, carpeting, luggage, rope
Polyvinyl chloride	$-(CH_2-\underset{\text{Cl}}{\text{CH}})_n-$	Nonflammable, resistant to chemicals	Water pipes, roofing, credit cards, records
Polystyrene	$-(CH_2-\underset{\text{C}_6\text{H}_5}{\text{CH}})_n-$	Brittle, flammable, not resistant to chemicals, easy to process and dye	Furniture, toys, refrigerator linings, insulation
Phenolics	Phenol-formaldehyde copolymer	Resistant to heat, water, chemicals	Plywood adhesive, Fiberglas binder, circuit boards

Adapted from P. J. Chenier, *Survey of Industrial Chemistry* (John Wiley & Sons, New York, 1986), pp. 252-264.

whose cross-linking was discussed earlier in this section. Table 23-5 lists some of the most important plastics and their properties.

Ethylene ($CH_2=CH_2$) is the simplest monomer that will polymerize. Through free-radical-initiated addition polymerization at high pressures (1000-3000 atm) and temperatures (300-500°C), it forms polyethylene:



The polyethylene formed in this way is not the perfect linear chain implied by this simple equation. Free radicals frequently abstract hydrogen from the middles of chains in this synthesis, and so the polyethylene is heavily branched with hydrocarbon side chains of varying length. It is **low-density polyethylene** (LDPE) because the difficulty of packing the irregular side chains gives it a lower density ($<0.94 \text{ g cm}^{-3}$) than that of perfectly linear polyethylene. This irregularity also makes it relatively soft, and so its primary uses are in coatings, plastic packaging, trash bags, and squeeze bottles in which softness is an advantage, not a drawback.

A major breakthrough occurred in 1954, when the German chemist Karl Ziegler showed that ethylene could also be polymerized with a catalyst consisting of $TiCl_4$ and an organoaluminum compound (for example, $Al(C_2H_5)_3$). The addition of ethylene takes place at each stage within the coordination sphere of the titanium atom, so that monomers can add only at the end of the growing chain. The result is linear polyethylene, also called **high-density polyethylene** (HDPE) because of its density

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